FEATURE ARTICLE

The Dreyfus model of clinical problem-solving skills acquisition: a critical perspective

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Context: The Dreyfus model describes how individuals progress through various levels in their acquisition of skills and subsumes ideas with regard to how individuals learn. Such a model is being accepted almost without debate from physicians to explain the 'acquisition' of clinical skills.

Objectives: This paper reviews such a model, discusses several controversial points, clarifies what kind of knowledge the model is about, and examines its coherence in terms of problem-solving skills. Dreyfus' main idea that intuition is a major aspect of expertise is also discussed in some detail. Relevant scientific evidence from cognitive science, psychology, and neuroscience is reviewed to accomplish these aims.

Conclusions: Although the Dreyfus model may partially explain the 'acquisition' of some skills, it is debatable if it can explain the acquisition of clinical skills. The complex nature of clinical problem-solving skills and the rich interplay between the implicit and explicit forms of knowledge must be taken into consideration when we want to explain 'acquisition' of clinical skills. The idea that experts work from intuition, not from reason, should be evaluated carefully.

Keywords: *clinical skills*; *Dreyfus' model*; *expertise*; *intuition*; *learning*; *medical education*; *novice to expert*

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Models are conceptual constructs that aspire to represent real things or processes that to a large extent are hidden for the senses and to the ordinary experience. Models have a role to describe, represent, explain, and 'translate' the world. Some good examples are the Feynman diagrams of electrodynamic processes, the fluid mosaic membrane, and the DNA double helix. Although models are partial and just approximations to the truth, they are not fictional or conventional at all. They try to represent their referents in a truthful and objective way with the hope to constantly improve or replace them with better approximations or more precise explanations (1).

Dreyfus and Dreyfus (2, 3) have offered a model of professional expertise that plots an individual's progression through a series of five levels: novice, advanced beginner, competent, proficient, and expert. In the novice stage a person follows rules that are context-free and feels no responsibility for anything other than following the rules. Competence develops after having considerable experience. Proficiency is shown in individuals who use intuition in decision making and develop their own rules to formulate plans. Expertise is characterized by a fluid performance that happens unconsciously, automatically, and no longer depends on explicit knowledge. Thus, the progression is envisaged as a gradual transition from a rigid adherence to taught rules and procedures through to a largely intuitive mode of operation that relies heavily on deep, implicit knowledge but accepts that sometimes at expert level analytical approaches are still likely to be used when an intuitive approach fails initially.

This model, a product of philosophical deliberation and phenomenological research, was initially adapted by Benner and other nursing educators to explain the development of nursing skills (4). However, this was not without debate, which still remains. Hargreaves and Lane criticized Benner's model, a linear model of skill acquisition that cannot sufficiently explain the everyday experiences of learning (5). Thompson (6), Purkis (7), and Rudge (8) criticized Benner's and Dreyfus' models because of their apparent absence of social structure or social knowledge. English pointed out that Benner's and

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Dreyfus' models fail to identify expert nurses because they neglect to specify objective qualifications for expertise (9). For Effken, the terms 'expertise' and 'intuition' do not have operational definitions: 'structured measurement has been elusive because of the complexity of the domain and the degree to which skill is embedded in a particular situation' (10). Gobet and Chassy, in contraposition to Dreyfus' and Benner's phenomenological philosophy, suggest an alternative conceptual framework to understand the role of intuition in expertise (11).

Assuming that nurses' and physicians' skills are of the same nature, physician educators have 'translated' and adjusted such a model to explain clinical skills not only in terms of simple routine tasks but also in terms of the most symbolic skills, i.e., clinical problem-solving skills (12). Many authors express their support for this. For Daaleman, Dreyfus provides a model of knowledge and skill acquisition that is relevant to the training of physicians in practical wisdom (13). Batalden, Holmboe and Hawkins recommend assuming Dreyfus' ideas as a framework to understand medical competencies [14, 15]. The Accreditation Council for Graduate Medical Education (ACGME) recommends this model for curriculum-planning for residency training programs (16).

Contrary to the debate raised in academic nursing fields, judging by medical publications and recommendations from academic organizations, the current form of Dreyfus' model (2, 3, 17–19) is being accepted almost without explicit criticism from physicians. Thus, although there may be some debate among clinicians and educators, such a debate is not evident in published papers. The Dreyfus model is reaching out to the educative arena and thus plays an important role in modeling how physicians acquire clinical skills. This may generate important consequences for our education. As was mentioned in this introduction, even models that are born from science are not complete explanations or perfect approximations to the truth, and they might be erroneous. Different from those, the Dreyfus model comes from philosophical fields; this fact makes even more urgent a critical analysis and debate. This paper tries to stimulate both.

A brief inventory of the Dreyfus model

Referents

A very important requirement for any model is its referent, i.e., the object or process referred to by the model or that which the latter is about (20). The Dreyfus model postulates that when individuals acquire a skill through external instruction, they normally pass through several stages. It is undeniable that such a process implies the acquiring of some knowledge. This psychological result of perception, learning, and reasoning constitutes the Dreyfus model's primary referent. Because the acquisition of knowledge does not happen in a vacuum but in a very complex organ (the brain), it is desirable that any hypothetical construct that attempts to explain learning is defined not only psychologically but also neurologically (21). Unfortunately, neurological terms appear in the model only when Dreyfus gestures toward artificial neural networks to demonstrate that phenomenology can reveal objective structures of bodily praxis (18, 22). Therefore, we may say that the brain is a secondary or spurious referent of such a model.

Postulates and propositions

The Dreyfus model has been proposed in prose style. Because it is easier to analyze a model when its content is structured in clear and unambiguous sentences (propositions) capable of being evaluated as true or false to some degree, two lists have been created and are presented in Boxes 1 and 2. They were prepared after a careful review of Dreyfus' original works and summarize the model (2, 3, 17–19, 23–25). To contrast Dreyfus' ideas, the author proposes some statements (listed to the right of the boxes) that were produced after reviewing various psychological, neuroscientific, and philosophical works (1, 20, 21, 28–30, 34–66, 68–79).

History and scientific evidence

Some historical facts may be also interesting. The original model was not published immediately for public scrutiny. Four prior reports exist from the US Air Force (2, 23–25), where some observations carried out on the instruction of jet pilots are described by Dreyfus. In those reports, few original scientific studies were cited and standardized protocols were not utilized. The only recent change in the model is the addition of two stages ('master' and 'practical wisdom') (17) to the five originally proposed (2).

Philosophy

All models have philosophical roots; Dreyfus' ideas are based on phenomenology (18), a philosophical doctrine proposed by Edmund Husserl based on the study of personal experience in which considerations of objective reality are not taken into account. This view opposes scientific realism; for Husserl, the world of things 'is only a presumptive reality,' whereas the subject is the absolute reality (26). The world is also 'an infinite idea, a complete synthesis of possible experiences' (27). Thus, the reality is subject-dependent because a thing is a complex of sensations. Moreover, according to Husserl, introspection through ordinary experience rather than through experiment, analysis, and modeling can yield deep knowledge of the world (28). For Martin Heidegger, another key proponent of phenomenology, 'the word is the abode of being' (29, p. 280), and 'things become and are only in the word, in language' (30). In other words, reality is constituted in and through discourse. We smell this

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Box 1. Dreyfus's postulates versus alternative propositions

Dreyfus' referents 1. Cognitive processes and skills in terms of implicit knowledge. 2. Brain as a spurious referent. *Philosophical background*: Phenomenology 3. Doctrine based on the study of personal experience in which considerations of objective reality are not taken into account. 4. The reality is subject-dependent because a thing is a complex of sensations. 5. 'The word is the abode of being,' 'things become and are only in the world, in language.' Reality is constituted in and through discourse. 6. Rhetorical style. No citing of scientific evidence to ground their proposals. *Dreyfus main postulates* 7. Skills are automatic 'dispositions' stored in our minds. 8. Performance of skills is explained exclusively in terms of implicit knowledge. 9. There are no references to inverse and ill-defined problems. 10. Acquisition of skills of any kind can be explained with this model. 11. The acquisition of a skill is viewed as a gradual transition from rigid adherence to rules, to an intuitive mode of reasoning that relies heavily on deep tacit understanding. 12. A high degree of performance is attained when the individual works intuitively.	Referents 1. Cognitive processes and skills in terms of implicit and explicit knowledge. 2. Brain as one of the main referents. *Philosophical background*: Scientific realism 3. The thesis that there are real things, the world exists independently of the knowing subject. 4. The reality can be known objectively and is best explored scientifically. 5. Science distinguishes between words and their referents (atoms, stars, people, societies, etc.). This is why science does not study them semantically or discursively but experimentally. 6. Models that are representations of real things must be coherent with scientific evidence. *Alternative postulates* 7. Skills are lasting modifications in an individual's brain apart from habituation or memory that enable its owner to face new experiences. 8. There is not a pure skill that allows only implicit or explicit knowledge to contribute to performance. 9. Any model of clinical skills acquisition must recognize that it faces special kinds of problems: inverse and ill-defined. 10. A model should be specific for skills of different natures. 11. The acquisition of skill is viewed as a learning process in two ways: suddenly and gradually. All kind of stimuli is necessary to facilitate the trainee's learning, aside from rigidly following rules. 12. A high level of performance is attained when somebody is able to work intuitively, reflectively and analytically

philosophy in Dreyfus' original work on the model of skill acquisition (2) and we discover his explicit adherence to phenomenology, especially to Heidegger's existential phenomenology, in one of the most authoritative texts on these matters: 'Being in the world: a commentary on Heidegger's "being and time"' (31).

Adaptation to clinical medicine

For the medical field, the model has been adapted with minor changes. For example, Dreyfus' main postulates are that the 'immediate intuitive situational response is the characteristic of expertise' (17, p. 42), and that most expert performance is ongoing and non-reflective: 'fluid performance happens unconsciously, automatically, naturally' (3, p. 32), and 'the expert driver generally knows how to perform the act without evaluating and comparing alternatives' (3, p. 33). Medical educators have proposed a hybrid model where masters are highly intuitive as well as reflective: 'the master is the practitioner who self-assesses and self-regulates and reflects in, on and for action' (12). This current statement contradicts the original model. Frequently, it is also stated by physicians that the model postulates that experts use intuition where empirical and propositional knowledge

Box 2. Dreyfus' postulates versus alternative propositions

Dreyfus' model stages propositions	Alternative propositions
Novice 1. A novice follows rules. 2. Does not feel responsible for anything other than following the rules. 3. Needs to bring its behavior into conformity with the rules. 4. Learning is free of context. *Advanced beginner* 5. Begins to gain experience in real scenarios. 6. Begins to understand his environment with its contextual features. 7. Learns 'instructional maxims' about actions. 8. Learning still occurs in a detached analytic frame of mind. 9. Does not experience personal responsibility. *Competent* 10. Develops an emotional attachment to the task. 11. Learns 'guidelines' (principles formulated by instructors, which dictate actions in real situations). 12. Competence comes only after considerable experience. *Proficient* 13. Learner uses intuition to realize 'what' is happening. 14. Uses memorized principles called 'maxims' to solve problems and determine the appropriate action. 15. Prior experiences provide patterns for future recognition of similar situations viewed from similar perspectives. *Expert and master* 16. Work intuitively on any problem. 17. No longer needs principles. 18. Capable of experiencing moments of intense absorption in his work.	1. Novices are not passive learners who just follow 'rules.' 2. Novices acquire information that allows them to grasp the nature of skills (understanding is a prerequisite to learning). 3. Novices need freedom. 4. Learning cannot be detached from context. 5&6. Even at the pre-beginner stage, learners gain experience and understanding of context; information, context, and experience cannot be separated. 7. Maxims are a few explicit 'prescriptions' that are learned at any stage. 8&9. There is always an emotional attachment to the task even at novice stages; hence there is always an experience of personal responsibility. 10. Again, affect is always linked to any cognitive task. 11. Learns to solve inverse problems, but those cannot be solved following rules, maxims, or guidelines. 12. Competence comes after learning to solve inverse problems. 13. A proficient learner, although esteeming its intuition, knows that it is not enough to realize 'what' is happening. 14. A 'proficient' performer tries to solve problems in novel and imaginative ways; he does not use only specific 'maxims' because they are just general recommendations. 15. Humans are 'pattern seekers and makers' even at pre-proficient stages. 16. Experts esteem intuition but are far from limited to a passive acceptance of it; experts analyze, critique and elaborate ideas. 17&18. For an expert, intuition only represents a portion of the problem solving process, which is always analytical besides intuitive. Experts need implicit but also explicit knowledge.

does not yet exist. Actually, the original model was proposed the other way around: experts work intuitively on every problem and only use other types of knowledge in a few cases when intuition fails.

The following paragraphs will discuss the most controversial aspects the Dreyfus model proposes. The main body of this paper will go further about the referents and basically will clarify what kind of knowledge the model is about and will review its coherence with problem-solving skills; some relevant scientific evidence from cognitive science, psychology, and neuroscience will also be reviewed. The central idea of intuition as a major definition of expertise will be discussed in some detail. This is also a good time to advise that this manuscript does not have

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any intention to be 'ecumenical.' Readers interested in favorable opinions and sympathetic papers of the Dreyfus model are urged to read several of the publications included in the references (4, 12–15, 32, 33).

Types of knowledge and the Dreyfus model

Because one of the most important referents of the model is knowledge, it would be of some benefit to review that concept. There are many kinds of knowledge and several ways of grouping these kinds into large categories (34). A division of knowledge that is relevant when analyzing Dreyfus model is into know-that and know-how. Traditionally, explicit knowledge or 'knowing that' has been understood as expressible in some languages; it can be attained easily from any codified information (35). By contrast, 'knowing how,' tacit or implicit knowledge, as it was proposed by philosopher Michael Polanyi, is not expressible in some languages. It is considered intuitive – acquired through practical experience – and as such, is subjective and contextual, and cannot be readily made explicit or formalized (36). Polanyi also suggested the supremacy of such implicit knowledge: 'While tacit knowledge can be possessed by itself, explicit knowledge must rely on being tacitly understood and applied. Hence all knowledge is either tacit or rooted in tacit knowledge' (37).

In psychology, the knowledge gained in implicit learning is defined by using several criteria (38). It is not fully accessible to consciousness. The learner cannot provide a full verbal account of what he has learned. Implicit knowledge does not involve processes of conscious hypothesis testing. In addition, implicit knowledge is preserved in cases of amnesia; thus, implicit learning relies on neuronal mechanisms other than the hippocampal memory system (39). Implicit knowledge is stored as abstract – and possibly instantiated – representations rather than aggregate or verbatim representations. This knowledge may also be inflexible because of its non-hippocampal base (40).

Knowledge that represents its content, attitude, and its holder explicitly is on the higher-order thought theory, conscious, and is considered explicit. Explicit mental representation is required to refer in verbal communication and thus a link emerges between explicitness and consciousness (41). The explicit processing of knowledge includes perceptual, cognitive, and motor processes, such as stimulus selection and search, attention focusing and maintenance, memorization, computation, decision making, response selection, and execution (42).

Recently, neuroscientists have proposed the Competition between Verbal and Implicit Systems (COVIS) model to explain the brain functional specialization and localization for the processing of these two types of knowledge (43). The verbal (explicit) system is mediated by frontal brain areas, such as the anterior cingulate, prefrontal cortex, and the head of the caudate nucleus. The implicit system is mainly mediated by the tail of the caudate nucleus and a dopamine-mediated reward signal (44, 45). The role of the basal ganglia in implicit learning and knowledge has been investigated through the study of people with Huntington's or Parkinson's disease (46, 47). Besides the COVIS model, there is evidence that the frontal lobes appear to be involved in the evaluation of implicit knowledge in making conceptual fluency judgments (38). Hippocampus-dependent memory systems subserve explicit memory formation (40).

There is considerable evidence in favor of this 'specialization' and division of knowledge (38, 41, 48, 49). However, there is not any evidence that sophisticated skills are performed either without a rich connection of both neuronal subsystems or without a rich interplay of both domains of knowledge. Galanter and Smith observed that even in subjects who are not engaging in conscious hypothesis testing, they can still notice that there is a pattern and can develop explicit knowledge of it (50). Individual learners, during motor skill practice, can discover the correct solution to a movement problem using either their implicit, explicit or a combination of both domains of knowledge; each approach leads to motor skill learning (51). The serial reaction time task, a classical example of 'implicit' knowledge acquired during sequence learning, is available for intentional control and is, in this sense, explicit (52). Automatic and intentional forms of processing can be brought under intentional control (53). Besides, explicit knowledge is an important and active variable that influences problem-solving processes, especially problem representation. Individuals who have accumulated considerable explicit knowledge in a domain represent problems more efficiently than individuals without extensive knowledge bases (54). In the face of strongly held explicit beliefs, knowledge gained through implicit learning is disregarded (55). Hence, in normal humans, it is difficult to develop a pure task that allows only implicit or explicit knowledge to contribute to performance. In particular, sophisticated skills are fueled by explicit knowledge.

Although the Dreyfus brothers recognize this division of knowledge, they believe that skills are exclusive instances of know-how or implicit knowledge: 'you can ride a bicycle because you possess something called "know-how," which you acquired from practice and sometimes painful experience' (3, p. 16). The Dreyfus brothers assert that when we perform a skill, we basically execute implicit knowledge without a connection to explicit knowledge. They believe that skills are automatic dispositions that cannot be readily made explicit (2, 3). They go further and propose that the net effect of learning is intuition and define it in terms of implicit knowledge: 'when we speak of intuition or know-how, we are referring to the understanding that effortlessly occurs upon seeing similarities with previous experiences. We shall use intuition and know-how as synonyms' (3, p. 28). In summary, Dreyfus and Dreyfus define skills at expert level almost exclusively in terms of implicit knowledge.

A critical point is to accept whether or not clinical problem-solving skills are implicit in nature or if they are predominantly dependent upon implicit knowledge. As we reviewed above, it is difficult to develop a task exclusively in terms of implicit knowledge. Even more importantly, clinical problem-solving skills are also instances of explicit knowledge. The clearest cases of explicit knowledge of a fact are representations of one's own attitude of knowing that fact. Knowledge capable of such fully explicit representation provides the necessary and sufficient conditions for conscious knowledge (41). This is the case when a physician evaluates a patient. Although he is not aware of all of the cognitive steps needed to make a diagnosis, he needs to be conscious of at least of the following events: characterization of a patient's symptom, valuation of a patient's sign, and solicitation of a diagnostic test. Furthermore, physicians explicitly provide a representation (diagnosis) and express the degree of accuracy or inaccuracy and can judge their representations to be true, false or undecided. Hence, it is reasonable to accept that making a diagnosis also subsumes an explicit dimension of knowledge. Therefore, a model that does not respect the complex and rich interaction between both domains of knowledge will have difficulty explaining skills that are not just routines but instead very complex tasks, i.e., finding solutions to problems.

Inverse problems and clinical problem-solving skills

We will start the discussion of this section by pointing out that there is not only one type of problem, but several types. Most problems can be classified into direct, well-defined problems and inverse, ill-defined problems. Direct or forward problems are of the following type: given C (causes) $\rightarrow$E (effects), find E (effects), where ($\rightarrow$) symbolizes the causal relationships (29, pp. 145–164). These types of problems call for analysis, or progressive reasoning, either from premises to conclusions or from causes to effects. In contrast, an inverse problem is a more complicated problem of the following type: given the clinical data E (effects = symptoms) and the acceptable causal hypothesis $C_1 \rightarrow E$, $C_2 \rightarrow E$, ..., $C_n \rightarrow E$, find the original cause C. Inverse problems require synthesis, or regressive reasoning, from conclusions to premises or from effects to causes. Inverse problems also are ill-defined problems in the sense that a simple solution may not exist, there may be more than one solution, or a small change in the problem leads to a big change in the solution (56).

Well-defined and direct problems have a clear path to a solution. The problem may be solved by using a set of recursive operations or algorithms (57, 58). In contrast, the cognitive processes involved in the solution of ill-defined problems are far more complicated and still ill-understood. In the case of ill-defined problems, all aspects of problem formulation are challenging. Most are fuzzy problems, often difficult to delineate and even harder to represent in a way that makes them solvable (59). In addition, inverse problems imply a novelty for each case, and expertise should reflect an ability to react to situations that experts have never encountered before. In this context, problems cannot be solved 'automatically' or only 'intuitively.'

The Dreyfus model has been derived from observation of the performance of experts, such as jet pilots and dancers, experts who are used to tackling direct problems. Is it correct to use this model also to explain the performances of experts who are used to tackling inverse problems? It is plausible that often the skills involved in solving direct problems are not the same as those involved in solving inverse problems. Think about the skills needed to solve this short list of inverse problems: to 'guess' the intention of a person from his/her behavior, to discover the authors of a crime knowing the crime scene, to 'imagine' an internal body part from the attenuation in intensity of an X-ray beam, to guess the premises of an argument from some of its conclusions, or to diagnose a sickness on the strength of its symptoms. The investigation of those problems does not proceed downstream, from premises to conclusions or from causes to effects. Working on all those problems involves reversing the logical or causal stream. In medicine, physicians face inverse problems all of the time. In fact, the typical diagnosis problem is not the direct problem of inferring syndrome from disease, but the inverse problem of guessing disease from symptoms (60). Anyone who wants to propose a model to explain how we develop clinical problem-solving skills must recognize carefully that the skills used to solve inverse problems are of a different nature than the skills used to solve direct problems. A model should be specific for skills of different natures; the Dreyfus model is not specific enough.

Rules and context

In the Dreyfus model, a novice should memorize rules and should not feel responsible for other things: 'to improve, the novice needs monitoring, either by self-observation or instructional feedback, so as to bring his behavior more and more completely into conformity with the rule.' (2, p. 7). Besides, the Dreyfus model supports the idea that at proficient and competent levels, performers should have developed 'personal guidelines and maxims' in order to be able to deal successfully with tasks

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and problems (2, 3). Why do we have to assume that these Dreyfus propositions are right? Is that the way we learn skills of explicit or even of tacit nature? Is it a good idea to memorize rules at novice stages? Do proficient and competent physicians solve diagnostic problems using just a set of 'personal' rules and maxims?

Early problem-solving research proposed the 'general problem solver model.' In this model the solution of a problem is conceptualized as a movement between two states: a starting state, named 'problem space,' and a final state named 'goal state' (58). There are 'rules of transition' which refer to those functions that move the system from one state to another, and there are also heuristics tools, rules that determine which moves are to be made in the problem space. Although this model gives great value to the use of rules, it should be recognized that these components are well suited for solving well-defined and direct problems, where the space and transitions between states are unambiguous (59). However, the model offers no solution whatsoever for dealing with inverse problems, for which there do not exist simple rules to solve them.

In medicine, although there are clinical guidelines and algorithms available that can help physicians deal with some problems, physicians acknowledge that these 'rules' are just general recommendations. Besides, physicians use 'guidelines' after they have transformed an inverse problem into a direct one. This is after diagnostic hypotheses have been generated. However, there is not a recipe to generate hypotheses. Furthermore, physicians use heuristic rules, such as Occam's razor regarding parsimony, but these 'rules' are general recommendations. They are explicit (not personal), and still it is not well known what impact they have on clinical problem-solving skills (61).

Rules are instructions for doing something, and even when they may be constructed as a mapping of possible actions (algorithms), they do not describe or explain any particular event or thing because they prescribe what to do. If we accept that knowledge has a transferable content that has been encoded and externalized in cultural artifacts, such as a book, then we should recognize that rules are not the sole element of that content, because knowledge consists of thousands of concepts, propositions, and theories. This knowledge allows us to grasp the nature of disease; understanding is a pre-requisite to learning. The development of clinical reasoning skills for medical students is dependent on basic science achievements (62, 63). Novices, who rely on biomedical knowledge, solve complicated diagnostic problems with more success (64).

Believing that students should only memorize rules has a dark side and can cause deleterious consequences. When rules are available for everything, novices can spare the effort of imagining a different way to solve an inverse problem. Hence, they would tend to proceed to solve problems in a rather mindless way. We should reflect on the fact that to learn, students need all kinds of stimuli, such as propositional from books and experience. But they also need freedom to develop the talent to produce diagnostic hypotheses by spotting, inventing, and sometimes guessing.

Other elements to analyze are Dreyfus ideas that learners at pre-competent stages have a complete ignorance of the 'context,' and that the education at this level should be decontextualized: 'normally, the instruction process begins by decomposing the task environment into context-free features which the beginner can recognize without benefit of experience' (2, p. 7). Contrary to such an idea, we should acknowledge that everything in our world, including concepts, is interrelated. Learning, as any other event, happens under specific conditions and should not be detached from the real experience. Medical students always face the context. Of course, at the beginning, there is not enough insight into every detail. However, students' minds are not like computers following a program; they have some ideas, some approaches, and some knowledge of the context. For example, medical students can generate numerous diagnostic inferences, even without considerable clinical experience (65, 66). How can they do that if novices like them 'ignore' the context? Accumulating experience is not a passive recording. Learning is creative in the sense that it is new and not automatic to the individual. Even at the pre-beginner stage, learners gain experience and understanding of the context. Information, context, and experience cannot be separated.

Intuition

The Dreyfus brothers propose that intuition is the endpoint of learning and a key characteristic of expertise: 'the expert pilot, having finally reached this non-analytical stage of performance, responds intuitively and appropriately to his current situation' (2, p. 12). Hubert Dreyfus describes a master as one with a lot of experience who produces almost instantaneously appropriate perspectives, who thinks intuitively, not analytically, and who ceases to pay conscious attention to his performance turning it unconsciously: 'the expert, like masters in the "long Zen tradition" or Luke Skywalker when responding to Obi Wan Kenobi's advice to use the force "transcends" "trying" or "efforting" and "just responds"' (67, p. 22).

Adults often learn to drive a car, type, play chess, ski, etc. In most cases we perform such skills intuitively, quickly, unconsciously, and 'just respond.' These everyday skills are relatively easy to acquire, at least to an acceptable level. It is plausible that some steps required to perform a simple task are so fast that we consider them on an unconscious level even though we are alert and oriented. Neuroscience tries to explain that there are two kinds of neuronal aggregations in the brain's organization: one is constituted of heavily interconnected neurons with long-range axons (named workspaces) and the others are system sets of specialized neuronal processors (perceptual, motor, memory, evaluative, and attentional) with short axons (68). The latter ones are not enough to perform tasks that require great effort, so the workspace neurons are activated, making the effort conscious. This mobilization is greater with complex cognitive tasks (68, 69).

However, the popular conception that some simple everyday skills are performed fast and 'unconsciously' can explain neither the performance of difficult tasks nor the acquisition of sophisticated skills (70). In the case of problem-solving skills, empirical studies have demonstrated a distinction between expert and novice problem representation in terms of the time spent on various stages of the problem-solving process. Contrary to the idea that experts dedicate less time than novices, Lesgold (71) found that experts spent more time than novices determining an appropriate representation of the problem. Experts spent more time comparing their knowledge to the information they needed to discover in order to best represent the problem.

Even skilled rapid motor production, as in typing, is not simple nor is completely automatic. Studies showed that expert typists look ahead to prepare for what comes next. They acquire complex representations and skills to anticipate future actions (72). Something similar happens in music, where the mark of expert performance is the ability to control one's performance and its results; there is not such a thing as an automatic and immediate response. Expert music performance requires several different representations: 'imagined music experience' (desired performance goal), 'playing a piece of music' (how to execute the performance), and 'listening to the played music' (hearing one's performance) (73). The resulting music performance should not be seen as a fixed and automated sequence of motor actions. It should be viewed as a flexible, controllable outcome based on these representations (70).

Consequently, it is hard to believe that the whole clinical problem-solving process is intuitive in the sense that it is unconscious, effortless, and automated. Although the use of 'pattern recognitions' and 'illness scripts' can happen in an automatic way, especially when data or a prior experience triggers a possible diagnosis, this explains only one state of the whole problem-solving process. Good physicians, although esteeming intellectual intuition because of its suggestive power, know that it can be dangerous: first, because intuition does not have demonstrative force, and second, because intuition is never fine enough. Intuition, as a very fast and almost instant inference, consists of showing rather than demonstrating; in proving in a brief and imperfect way, and in rendering plausible the hypothesis that has been invented. It is a kind of rudimentary reasoning that uses incomplete evidence, visual images, and analogies (prior experiences) rather than complete data, refined concepts, and detailed inferences (74). A diagnosis formulated in an intuitive way will have to be worked out in a rational way and then tested by the usual procedures. This is because the suspicion generated by the illness scripts and pattern recognitions are not proof of a diagnosis. Further, this is why we use a lot of auxiliary tests and image studies. Expert clinicians intentionally avoid any tendency toward automatization as they often lose control of many relevant aspects of a clinical encounter. Ericson called this 'deliberate practice' (70).

There is evidence that experts use two modes of thinking: analytic (hypothetic–deductive) and non-analytic (pattern recognition), even in perceptual specialties (75–78). Both modes of thinking are part of a continuous process. Expert physicians do not use analytic reasoning only after a failed attempt with non-analytic reasoning or the other way around. Clinical medicine is one of the more complicated and challenging professions; it is very simplistic to explain problem-solving processes starting and ending with intuition. Many diagnostic errors are due to overconfidence and heuristic availability, and some errors occur during non-analytic reasoning (79). Intuition, because it is brief and readily accomplished and grasped, must be expanded to be validated.

Implications and conclusions

Any model is a representation of a thing, and in this representation two elements play important roles: the represented and the representing things. With this pair of elements we can make diverse kinds of representations: factual–factual (a scale model), factual–conceptual (a theoretical model), factual–semiotic (a scientific text), and semiotic–factual (a text illustration) (1). The acquisition of skills is a learning process and is obviously factual. Hence the Dreyfus model attempts to be a factual–conceptual model, a theory or at least an outlook of how we acquire diverse skills. Any fact–concept correspondence is of course difficult and not of the one-to-one type. However, because it tries to be truthful, a theory must attempt to be coherent and related to the facts.

Although the Dreyfus model is not taken strictly as a 'prescription,' it is plausible that its descriptive face is influencing us to generate a worldview, a general outlook of how we learn and teach medicine. Every worldview has an effect on our actions and policies. And here is the point of major implication, because this model can influence educative policies, recommendations, and guidelines. This model can also generate unhappy contradictions. For example, it has been said that the Dreyfus model provides us with a framework for consistency within the evaluation system (80). How can this model

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help us to ground our evaluation system if the model suggests explaining physicians' performance in terms of implicit knowledge and intuition? By definition, if implicit knowledge is not expressible in some language, then it is inaccessible to evaluate. Certainly we need more debates and we need to evaluate this model not only in light of philosophical but also of scientific considerations.

Although the Dreyfus model could partially explain the 'acquisition' of some skills, it is another matter as to whether it can explain the acquisition of clinical skills. The occurrence of inverse problems and the rich interplay between the implicit and explicit domains of knowledge must be taken into consideration when we want to explain 'acquisition' of clinical skills. The idea that the net effect of education and training in medicine is that we start developing intuition about what we are doing must be revised and evaluated carefully.

Using this model in a prescriptive way must elicit a more critical eye to see if novices must receive an education where rules are the only important things to learn in a decontextualized environment. Finally, we must acknowledge the complexity of all the processes implied in learning. We cannot merely accept the temptation to oversimplify these complex processes, and ignore intentionally or not information from science, in particular from cognition, psychology, and neuroscience.

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